Evaluation of a Novel Model-Based Registration Algorithm for T1 and ECV Mapping on Clinical Data

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Target Audience This abstract is intended for people interested in cardiac MRI, tissue mapping and image analysis techniques.

1. Purpose

Myocardial T1 and extra cellular volume (ECV) mapping is currently of great interest due to its ability to quantitatively characterize the myocardium and thereby detect diffuse myocardial diseases such as amyloidosis. Since these maps are pixelwise calculated from a set of T1-weighted images, any motion between them will disturb the mapping if this motion is not corrected first. Straightforward use of standard state-of-the-art image registration algorithms is however complicated due to contrast inversion, signal nulling and partial volume effects. We have previously developped a new registration framework to overcome these difficulties and obtain motion corrected T1 and ECV maps which we validated on images of healthy volunteers [1]. Since patient data may be of inferior quality and may show pathological deviations, the purpose of this study is to assess the accuracy of our method on a significant number of actual patient images.

2. Methods

We selected native and enhanced T1-weighted image sequences, acquired with respectively the 5s(3s)5s and the 4s(1s)3s(1s)2s MOLLI schemes, from patients in our CMR database with histologically confirmed cardiac amyloidosis in a period of two years (n=29; M=24, av. age = 72+/-10 years). The 2D+time scans, including both short axis (SA) mid-cavity and basal slices as well as horizontal long axis (HLA) slices, were recorded using a 1.5 T MR scanner (Philips Healthcare, Best, the Netherlands) and a 6-channel (Achieva) or 32-channel (Ingenia) cardiac phased array receiver coil. For the enhanced scans, 0.15 mmol/kg of gadoburtol (Gadovist, Bayer Schering) was administered.
Our registration framework first aligns the images in a single T1-weighted sequence by combining a data-driven initialization with a model-based refinement. The data-driven registration applies a global optimization approach to define the optimal reference image and optimal registration sequences for pairwise image registration. Afterwards, the model-based registration iteratively improves the registration by minimizing the error on the T1 curve fit which is achieved by minimizing the sum-of-squared differences between the original images and ideal model images derived from the curve fit. A motion-free ECV map is additionally obtained by registering the native and enhanced reference images (inter-scan registration) using the mutual information similarity measure. A non-rigid B-spline motion field was calculated for all registrations. To assess the accuracy of the motion correction, the endo- and epicardium in all T1-weighted images were manually delineated and mean dice coefficient (DSC) and mean boundary error (MBE) were determined before and after registration. Statistical significant differences before and after motion correction are assessed using the two sided Wilcoxon signed rank test (p=0.05) while the Wilcoxon rank sum test (p=0.05) is used to compare the results of the different slices (SA and HLA). A subset of image sequences showing substantial motion was defined based on a mean DSC smaller than 85% before motion correction.

3. Results

The results are summarized in Fig. 1. The DSC and MBE across all patients did not change for the native (n=68) and enhanced scans (n=55) while the inter-scan registration significantly increased the DSC and decreased the MBE (n=47). The results over the different slices (SA and HLA) were grouped because no statistical significant differences between them were found before or after motion correction for both DSC and MBE. When only the results of the sequences with substantial motion were analysed, a significant improvement of DSC and MBE after motion correction was observed for the native (n=13), enhanced (n=14) and inter-scan registration (n=37). The mean septal native T1 and ECV in the SA sequences with motion changed respectively from 1088±69ms to 1065±50ms and from 47±12% to 45±14% after motion correction. Visual apparent misregistration was observed at the lateral wall in 1/55 enhanced scan and in 2/47 inter-scan registrations.

4. Discussion

When motion is present, the proposed algorithm is able to correct for it. Furthermore, registration is particularly beneficial for ECV mapping since larger initial motion is present between the different T1-weighted sequences. The residual misregistrations we observed in three cases were due to 3D out-of-plane motion resulting in significant cardiac shape variation. This can not be properly corrected by 2D in-plane registration only, because even with perfect retrospective image alignment, the tissue regions that are aligned do not physically correspond.

5. Conclusion

Our approach for motion correction was able to significantly improve the alignment of separate T1-weighted images and thereby the quality of the T1 and ECV maps when substantial motion was present in the original scans which were acquired in true clinical conditions. The method is however not able to correct for large out-of-plane motion.

Reference S. Tilborghs et al. (2017). *Robust Model-Based Registration of Cardiac MR Images for T1 and ECV Mapping*. FIMH 2017.

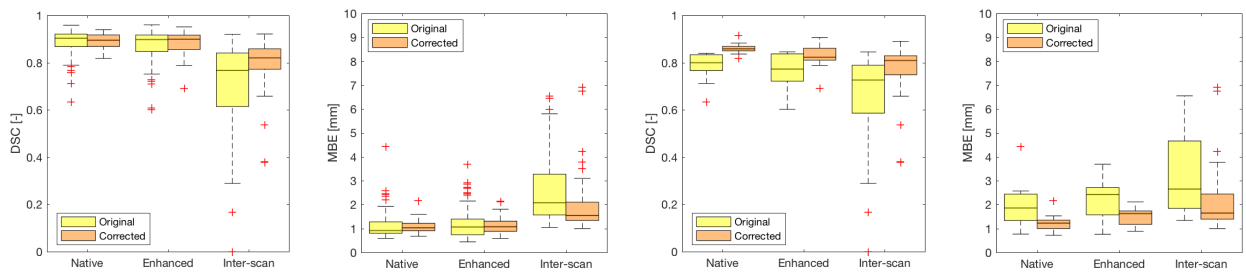

Figure 1: Mean DSC (a,c) and MBE (b,d) before and after motion correction: (a,b): all, (c,d): cases with substantial motion.